# Managing grasslands biodiversity at a landscape level to foster ecosystem services in intensive cereal systems: from ecological knowledge to collective action

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Second International Symposium on Integrated Crop-Livestock Systems
Porto Alegre, Brazil - 8-12 October 2012

# *Managing grasslands biodiversity at a landscape level to foster ecosystem services in intensive cereal systems: from ecological knowledge to collective action*

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*Abstract*

Effective solutions for integrating agricultural development and conservation of biodiversity at the landscape scale remain to be identified. We present a case study in an intensively farmed French cereal plain, where the reintroduction of grasslands has been proposed first for conservation purposes in order to protect the Little Bustard, a highly threatened bird species. Monitoring the effects of grassland "experimental" implementation revealed other beneficial effects on virtually all components of the trophic web in these agro-ecosystems, particularly at the landscape level. Indeed, in intensive cereal systems, perennial habitats such as grasslands are radically different from annual crops in terms of level and frequency of disturbance (plowing, planting, spraying etc.). In these highly fragmented and disturbed habitats, the presence, abundance and distribution of grasslands therefore have a critical role in ecological and environmental regulatory processes. We provide evidence that grasslands, particularly alfalfa, are the support of many ecosystem services, such as pollination, biological control, in addition to forage production. To maximize their provision, it is critical to rationalize the inclusion of grasslands in the cropping system (in time, space and according to management practices). However, currently, grasslands are severely depleted by farmers who privilege cereal crops for economic reasons (including CAP subsidies). We therefore raise the issue of whether crop allocation at the landscape scale can be changed without public funding, in order to increase the proportion of grasslands. In other words, how to overcome the reluctance of cereal farmers to produce forage crop? A solution explored here is to identify the interdependencies between farmers related to the ecosystem services grasslands provide at the landscape scale. The recognition of grassland emergent functions when considered at the landscape scale gives them a status of common good: a good that should be collectively managed to maximize ecosystem services. This consideration leads to involve new stakeholders such as citizens, scientists, government bodies or NGOs in the collective management of grasslands and opens an innovative way to reconcile agriculture and conservation at the landscape scale.

*Key words*

Agro-ecosystem, ecosystem services, grasslands, cereal crops, biodiversity, design, collective action, commons

*Introduction*

In response to the growing concerns about environmental crisis, ecosystem based approaches are increasingly being called upon (Grumbine 1994). Protection and management of whole ecosystem structure and functions however needs integrating ecological, social, economic and institutional factors, and therefore call for holistic approaches in contrast to targeted actions in order to protect species of conservation concern. Ecosystem-based approaches require improving our understanding of the underlying biophysical processes in order to take decisions at the right spatial and temporal scales (Anderies, Janssen et al. 2004). Given that individual management actions can affect multiple interacting ecological processes, a critical aspect is the coordination of decisions among interacting stakeholders (Granek, Polasky et al. 2009; White, Costello et al. 2012). Indeed, coordinated management is supposed to optimize ecosystem state, the provision of multiple ecosystem services and consequently the joint value of an ecosystem to society (Slocombe 1993; Stallman 2011; White, Costello et al. 2012). However, coordinating decisions among ecosystem managers and stakeholders is a difficult task, which raises particular and complex governance issues. Two main approaches have been proposed for the provision of ecosystem services as public goods: governmental or market regulations (Swinton, Lupi et al. 2007). However a growing number of studies advocate for the potential role of a “cooperative” approach (Ostrom 1990; Stallman 2011). In studies of socio-ecological systems, many variables have been identified as affecting the patterns of interactions and outcomes observed in empirical studies (Anderies, Janssen et al. 2004; Olsson, Folke et al. 2004), and frameworks have been developed to enhance our understanding of the conditions under which cooperation is maintained or will evolve (Ostrom 2007).

Agro-ecosystems represent a very interesting, though under studied, socio-ecological systems. Most studies suppose that the stakeholders in charge of management of ecosystem services are identified, that cooperation among them already exists, and that the resources used are considered as stocks to maintain (Anderies, Janssen et al. 2004). Therefore management actions generally consist in regulating resource exploitation and solutions can be identified by problem-solving approaches. In contrast, in the case of agricultural ecosystems, collective action to maintain their sustainability is more complex: first, there is a spatial scale-mismatch between ecosystem services typically managed at territory or watershed levels and agriculture practice managed at the farm scale (Goldman, Thompson et al. 2007). Second, while in theory, ecological knowledge in such systems is probably enough to propose effective solutions in order to maintain ecosystem services (Pelosi, Goulard et al. 2010), the practical way to implement these solutions and involve stakeholders in the collective action is far from being achieved. Third, in agro-ecosystems, economic value of crop productions is a highly rewarded target, therefore in potential conflict with other services (particularly those in relation to environmental impacts). Last but not least, many people live within these agro-ecosystems, and therefore, there are many stakeholders, both quantitatively and qualitatively.

In this paper, we focus our analysis on such situations where solutions are not known initially, i.e. where potential services provided by agricultural ecosystems are multiple, interacting and dynamic. Management solutions to enhance their provision are generally unknown and require a complex design process, being all the more difficult since performance criteria are not known initially. In particular, solutions must be shared and viewed as effective and feasible by heterogeneous stakeholders with sometimes conflicting interests. In addition, in such systems, there is no legitimate designer or expert in charge of the design of such solutions: people in charge of designing and managing agricultural ecosystems (farmers, researchers, extension services, local authorities, naturalist organizations, etc.) are scattered and their actions are generally not coordinated. Hence the issue of designing relevant solutions to enhance the sustainability of an agricultural ecosystem raises in itself a governance problem.

In order to highlight the difficulties raised when looking for solutions to design sustainable agro-ecosystems, we propose to draw upon an empirical case, which to a certain extent can be considered as an ideal type. The agro-ecosystem considered is an intensive cereal cropped farming system in the west of France. Cereal farmland covers more than 50% of French farmed areas. In these systems, biodiversity loss, soil fertility degradation and water pollution have reached critical stages. The area under study is a habitat for various threatened bird species, which makes it a hotspot for conservation actions. We first describe a design process carried out by a research center in ecology (*Centre d'Etudes Biologiques de Chizé*, CEBC) that combines a "classical" scientific production of knowledge in ecology with the design of conservation actions. Then we analyze a second design process, which is in the continuity of the previous one, but which involves a wider group of stakeholders. It is carried out for the implementation of a short-scale fodder crop supply chain conducted by an agricultural cooperative (*Coopérative Entente Agricole*, CEA). Analyzing these two design phases under the framework of the most recent design theories, we highlight their main steps and originality. We reveal the importance and stakes of such design processes to develop locally adapted and accepted collective ecosystem-based management strategies. Finally we draw upon this analysis to discuss the literature on governance of socio-ecological systems.

### *Study area*

The study area, "Zone Atelier Plaine & Val de Sèvre" (South of *Département des Deux-Sèvres,* in the arable plain of Niort-Brioux (46°15'N, 0°30'W) is situated in *Région Poitou-Charentes*, western France. It is a 430 km$^2$ farmland intensively cultivated, mainly with wheat and winter barley, sunflower, maize, oilseed rape, alfalfa and grasslands. Hedgerows and small forest fragments are still present but irregularly distributed). Fields are however characterised by relatively small size (of about 4 ha on average). In 2010, cereals accounted for 44 % of the land use, grassland (including hay meadows, alfalfa, pastures, set-asides and fallows) c.15 %, and spring-sown crops c. 24%. The presence of 17 Annex 1 species of the EU Bird Directive (notably the Little Bustard) has led to the designation of half of the study area (207.6 km$^2$) as a Special Protection Area in 2004 (ZPS Niort Sud-Est, FR5412007). Mixed farming systems have been decreasing for the last 30 years, but cattle and goat farming remain, though a global shift toward industrial husbandry has occurred. The number of farmers has halved over the past 30 years, while average farm size has doubled (French agricultural general census, 2000).

### *Method and conceptual framework*

Our analysis was twofold. An ex-post analysis of the first design phase was carried out between May and August 2010. It was based on a literature review in addition to scientific reports or research projects produced by CEBC researchers. We also conducted 23 interviews with researchers of CEBC, government bodies, environmental associations, farming organizations and local authorities. These first interviews were aimed at reconstructing the design of conservation actions for the Little Bustard *Tetrax tetrax* (Berthet, Bretagnolle et al. 2012).

The analysis of the second design phase is based on an on-going intervention research study (Hatchuel and David 2007). Indeed, we accompany the design process led by local stakeholders while analyzing it. We started this study by carrying out 18 interviews between

January and February 2011 with members of the cooperative CEA (President, board members, manager, technicians and farmers), CEBC researchers and local authorities. We then contributed to the organization of a designed workshop in May 2011, the method of which will be presented below. We are currently following the implementation of the alfalfa local supply chain and the governance issues it raises.

Our theoretical framework is based on the Concept-Knowledge (C-K) theory (Hatchuel and Weil 2003; Hatchuel and Weil 2009). C-K theory is one of the most recent and general design theories. It focuses on the specificities of innovative design reasoning. The central proposition of this theory is a formal distinction between “Concepts” (C), i.e. proposals still partly unknown and requiring a design process (whether the proposal is achievable or not remains uncertain in the current state of knowledge); and “Knowledge” (K), i.e. proposals having a logical status (proposals can be assessed by anyone as being true or false). Knowledge is what designers already know or what they learn progressively during the design process. A central finding of the C-K theory is that a concept is the necessary departure point of a design process (Hatchuel and Weil 2003). The formalism proposed by the theory is a kind of map of design reasoning. We used the theory to analyze ex-post the design reasoning that was developed by scientists in the case studied, but that today is implicit. The first flow diagram we display below highlights only the key steps of this reasoning and does not intend to reflect in an exhaustive way all the reasoning of stakeholders over the past 15 years of the project, or to be chronological. Its construction was iterative and took into account feedback from the people involved in the design process.

## *Results and discussion*

### ***1. From a flagship species natural history knowledge to the role of grasslands in ecosystem function***

#### a) Improving the knowledge about Little Bustard biology to target efficient conservation actions

In order to stop the biodiversity loss in the agro-ecosystem of the *Région Poitou-Charentes*, naturalists targeted the conservation of a key stone species which was an apex predator, the Little Bustard, assuming that it was a mean to have the strongest impact on the ecosystem preservation as a whole (Andelman and Fagan 2000; Mace, Norris et al. 2012). The conservationists could have promoted a traditional approach such as excluding agricultural activities and establishing a nature reserve such as in National parks(Grumbine 1994). However economic interests were such that it was impossible (see also (Phalan, Onial et al. 2011)for the classical land sharing/land sparing debate). As a consequence, the starting point of the design process was to develop new agricultural practices that would make it possible to conserve the Little Bustard. No obvious or satisfactory solutions existed *a priori*. Therefore, “developing new agricultural practices to conserve Little Bustards in the cereal plain” is what in the framework of the C-K theory we qualify as an initial concept: an unknown proposal which is the starting point of a design process.

To begin with, CEBC researchers sought to understand the main causes of Little Bustard population decrease. They identified a parameter as being the most significant in terms of conservation strategy: female productivity (Bretagnolle and Inchausti 2005). Given the rapid decline of the Little Bustard in agricultural areas (> -13% per year between 1997 and 2002: (Bretagnolle, Gauffre et al. 2011), two complementary strategies were set: reproduction in captivity, and increase in habitat quality in the agro-ecosystem. The latter was the most important, and consisted in "improving reproduction capacity in the agro-ecosystem", that can be seen as a concept. This concept required the production of new knowledge regarding Little Bustard reproduction, as very little information was available about where and when this species bred, laid eggs, how chicks were fed, etc. Based on studies carried out between 1997 and 2001, researchers found that half of the clutches could not hatch, 40% of which was due to the destruction of nests by farming practices. In addition, nearly 40% of clutches arriving at hatching failed because of food shortage during the early chick rearing period, when chicks rely solely on insects (Inchausti and Bretagnolle 2005). This problem of chick food shortage was targeted as a priority by conservationists as it was a major limiting factor for Little Bustard fecundity. At this stage we can see in the flow diagram (Fig. 1) that various solutions had been proposed based on this knowledge progress, but this one has been particularly explored as it appeared to have a greater potential in terms of efficiency and feasibility.

### b) The use of metapopulation theory: toward a new representation of the agro-ecosystem ecological functioning

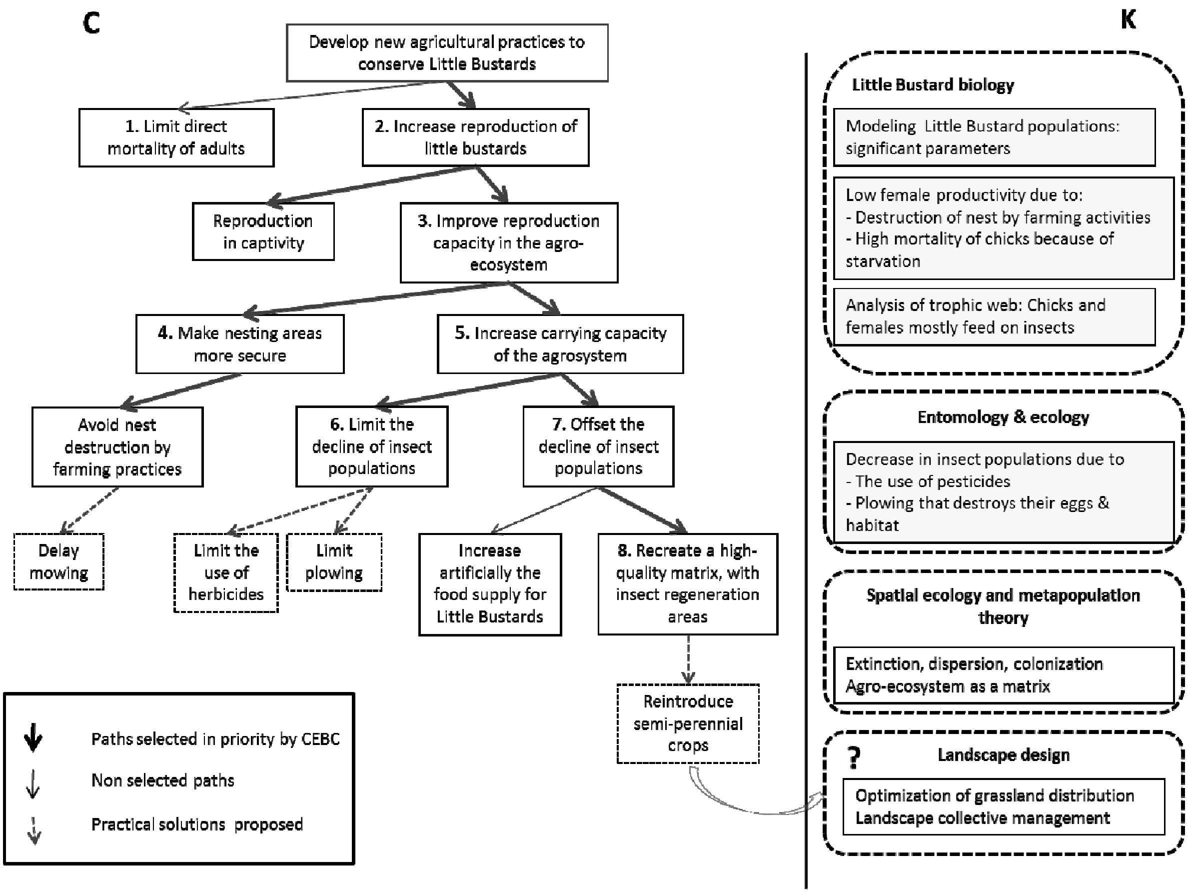
Aiming at maintaining a sufficient quantity of grasshoppers favored a new concept that eventually emerged from the previous one: "increasing the carrying capacity of the entire agro-ecosystem". Monitoring insects on the study site showed that the repeated application of herbicides that deprive insects of food and to a lesser extent of insecticides was a major problem and that plowing was found to destroy egg-laying habitats for grasshoppers (Badenhausser, Amouroux et al. 2009). In order to improve grasshopper populations, disturbance regime had to be lower, pesticides use had to be banned and breeding habitat for grasshoppers should be distributed optimally in space. Metapopulation theory was thus used, which actually changed the representation of the agro-ecosystem. This theory predicts that a local extinction of a population can be compensated for by colonization, provided that an adequate regional supply of the population exists and that individuals can disperse to new local habitat when population has gone extinct (Levins 1969; Hanski 1999). The agro-ecosystem was thus modeled as a matrix, composed of semi-natural areas (high quality habitat) and cropped areas (low quality habitat). This matrix is considered of high-quality if it allows for migration rates balancing the rate of local extinctions (Perfecto, Vandermeer et al. 2009)(see Fig.1: Path 7 & Path 8). Various options to regenerate grasshopper populations were thus explored: patches of land area purchased from farmers and excluded from production, fallows or grasslands. As grasslands are productive areas and have value for farmers, this solution was preferred since it was thought to be more acceptable for farmers. Moreover, grasslands were given priority compared to linear infrastructures (hedges, grass strips) because they contribute to diversify the landscape mosaic required for Little Bustards reproduction, being also nesting areas.

### c) Grasslands as a targeted object in terms of conservation management

Grasslands were then considered as a lever to reintroduce insect population regulations in a highly disturbed agro-ecosystem and regenerate the trophic web (an important target for Little Bustards that can be considered as an apex predator in such systems). However a new bundle of knowledge was needed: how to distribute such grasslands among annual crops in order to optimize grasshopper population size? Based on studies taking into account their dispersal distance and on empirical observation, grassland percentage in the landscape was estimated to lie between 10% and 20%, and the scientists set a target of 15% of agricultural land as grasslands, preferably randomly scattered across the landscape.

The design flow diagram, applied to knowledge-based conservation actions, shows that the method used was not problem-solving (i.e. trial and error), but a gradually targeted process using various representations of the agro-ecosystem. This innovative design reasoning made it possible to formulate new concepts, which then guided knowledge production. The first part of the design process was a quite classical conservationist reasoning. However the use of metapopulation theory introduced a spatial dimension and opened the door to ecological engineering initiatives, considering grasslands as ecological infrastructures that may restore regulation processes in the agro-ecosystem. However the design process was not finished yet and the question of how to develop grassland areas and manage their distribution was still an open question.

**Figure 1: A summary of the design reasoning led by CEBC researchers using C-K Theory formalism**




## *2. Restoring grasslands in the cereal plain: from theory to implementation*

CEBC ecologists proposed the conversion of cereal crops into grasslands as a local agri-environmental scheme (AES). Such AES was made feasible because the study site was a NATURA 2000 SPA; local, national and European authorities validated the scheme, and the CEBC was given the role of AES operator in this SPA. Hence researchers progressively became landscape matrix designers, by the way of reintroducing grasslands. Indeed, since 1995, the researchers have compiled a GIS database at the scale of their study area (450 km²) of the location of Little Bustards as well as crop use, allowing to develop targeted schemes with regard to Little Bustard location and also to monitor their effectiveness.

However this situation of centralized management strategy presents various shortcomings. AES are contracts with farmers intended to promote the implementation of environmentally friendly agricultural practices in return for an annual subsidy to offset the costs involved and possible income reductions. This system is very costly (compensations can reach 500€/ha/year), limited in time (5 years), and cannot be extended outside the SPA delineation (with a buffer of 2 km allowed in this precise case). Above all, as farmers have only slightly participated to the design of such practices, and perceive it as a constraint, their main motivation to adopt this solution is the financial compensation.

Therefore, other attempts aimed at restoring grassland areas were searched for, as an alternative to the government-funded economic compensation. These new solutions required the cooperation of ecologists with agronomists and social-scientists. A first solution considered was to make cattle breeders increase their fodder production. However many breeders are unable or unwilling to put more land into grassland as they prefer diversifying their sources of income, and actually maximize wheat income. A more innovative alternative is to make cereal farmers produce forage crops. However to a certain extent cereal farmers consider grasslands as non-productive areas, as there is no market for hay or silage. Exchanges exist only on an informal ad hoc basis, as cattle breeders generally grow their own fodder or buy compound feeds. Hence a critical condition to conduce cereal farmers to grow fodder crops was to create a market for fodder.

Pursuing the objective to find both efficient and sustainable solutions, the researchers looked for the fodder crop that would be the most easily adopted by regional farmers. Alfalfa was chosen first because it was historically grown in the region: it is pretty well adapted to the pedo-climatic conditions and suitable for goat cattle feeding, one of the main husbandry sectors in the region. Second, as a legume, alfalfa is also known for its agronomic interests such as atmospheric nitrogen fixation. Thus in addition to launch a large research program to identify the ecosystem services provided by alfalfa in a context of an intensive cereal cropped agro-ecosystem, the researchers explored the possibilities to create a market for fodder crops. However such solutions are difficult to set up by an actor external to the farming sector.

## 3. *From scientific-based to multi-stakeholder design process*

### a) A new partnership between ecology researchers and an agricultural organization to develop alfalfa production in the cereal plain

While ecology researchers enlarged progressively their knowledge base about agriculture, farmers and related organizations also initiated reflections to renew their practices in order to make them more environmentally friendly. This is the case of the agricultural cooperative CEA (*Cooperative Entente Agricole*) who decided in 2005 to initiate a shift in its strategy toward sustainable development. As the cooperative had very few skills with regard to environmental preservation, it started off with looking for partners. With the CEBC, the cooperative was proposed to set up a short-scale alfalfa supply chain. They agreed on this proposition not only as it seemed to be a systemic solution to local environmental problems, but also as it was in the scope of their activity to contribute to set up a supply chain. For the CEBC researchers, this was an opportunity to develop alfalfa production without public funding, and with the support of actors from the agricultural sector.

However although the project of alfalfa supply chain was agreed by both stakeholders, many questions remained open. At a first glance, this project was an opportunity for actors with rather conflicting interests to collaborate in the framework of common objectives. In reality the initial motivations and constraints of both parties were significantly different. Indeed the cooperative aimed to maximize alfalfa production while ecologists aimed to develop areas with as less disturbance as possible. “Grasslands” actually referred to different objects for each stakeholder.

Indeed the proposal of developing alfalfa crops in the cereal plain was the result of a long design process led by researchers. This design process had given alfalfa multiple properties that farmers were not aware of, such as insect population regulations or weed regulation (Meiss, Mediene et al. 2010). Other solutions had been left aside by ecology researchers as they were considered as less efficient. As a consequence, a crucial preliminary step to the project was to make explicit all the expected ecological properties, but also to express the properties expected by other stakeholders than conservationists. Moreover, there was a need to explore the variety of alfalfa production modalities and to decide collectively on their selection.

### b) Initiating a collective design process to set up common objectives

To tackle these issues, the project leaders decided to launch a collective design workshop in order to specify the objectives of the project and agree on priorities. It also aimed at looking for innovative solutions for the implementation of the project. Lastly, it was a first step in developing ad-hoc governance rules, in particular identifying the role that the cooperative should play. Before this workshop, the cooperative had planned to implement the project with a classical bilateral contract for alfalfa production with conventional practices. An expected outcome of the workshop was to re-open the alternatives for the implementation of the project. The design workshop was facilitated by a researcher in management sciences using the KCP method (Hatchuel, Le Masson et al. 2009), which was developed on the basis of C-K theory to foster innovative design. The method structures collective exploration into three steps: a Knowledge-phase (K-phase) that make it possible to share internal and external knowledge; a Concept-phase (C-phase) grounded by surprising and strongly contrasting propositions (“*concept projectors*”) that orient creativity; and a Proposal-phase (P-phase) aimed to synthesize the results and elaborate a design strategy.

The organization committee agreed on a list of 30 participants: CEA board members, technicians and member farmers; researchers in ecology and agronomy; local authorities’ representatives and extension services. The majority of participants were internal to the cooperative. However this workshop was also an occasion to gather stakeholders who did not know each other before. The two first phases were organized on a single day. The K-phase aimed to review the cutting-edge knowledge about alfalfa production and related environmental issues. Four contrasting concepts projectors were identified by the facilitators to help the participants explore a large array of alfalfa properties: for instance, “premium quality alfalfa”, or “alfalfa that farmers like to produce”. This phase drove participants to identify the need for external knowledge useful for the project. Then for the Proposal-phase, the facilitator carried out a thorough analysis of the results. The aim was to analyze the knowledge capitalized and to identify some frequently recurring and innovative propositions. The results were presented to the organization committee then to all workshop participants.

### c) Toward a creative resolution of conflicts

At the beginning of the process, naturalists and farmers had very different views and expectations about alfalfa: for naturalists, it was an ecological habitat whereas for farmers it was a productive area. The design workshop made it possible to extend the attributes of alfalfa, i.e. its design parameters and expected functions to build a common ground for all stakeholders. Antagonisms between key parameters were pointed out, such as harvest date or herbicide use, and flexibility possibilities were explored to overcome them. The alfalfa production modalities proposed were not focused on trade-offs between fodder production and nature conservation, but rather on the identification of new values that could be collectively created by farmers, such as enhancing pollination by staggering harvest dates or improving water quality by concentrating grasslands around drinking water catchments. The identification of such ecosystem services and of their potential related values highlighted strong interdependences between agro-ecosystem stakeholders, especially when considering the regulation functions of grasslands that most stakeholders were not aware of, e.g. biogeochemical cycles.

The spatial distribution of alfalfa plots can be controlled to enhance Little Bustard conservation, and they would then be dispersed. But such control would also be relevant to protect drinking water catchments or to optimize biological control, in which case other spatial distribution would be required. Thus, by increasing the number of targeted objectives, some have become antagonists. The design phase of the alfalfa supply chain project is thus an opportunity to explore feasible options and their related ecosystem service bundles. This makes it possible then to hierarchize and select collectively the ecosystem services to produce in priority. This exploration revealed the importance of coordinating grassland management at the landscape scale. According to the configurations of grasslands chosen by the stakeholders, the ecological and productive properties of the ecosystem will not be the same. This actually revealed the status of “common good” of the agro-ecosystem. Common goods refer to a field of the economy for which it is difficult to develop physical or institutional means for excluding beneficiaries although these goods are in limited quantity. The case of grasslands is interesting because it leads to thinking in terms of "design of common goods.”

So far, several strategies proposed to safeguard common goods have been identified, including those developed by local communities, and analyzed by Ostrom (Ostrom 1990; Ostrom 2000). She identified several design principles that help communities sustain and build their cooperation over long periods of time (Ostrom 2000). However, she considers common goods as an existing collectively-owned stock to manage. In our case, grasslands are private goods, but as soon as they are managed as common goods they have to be designed, as do also new farming practices and new modes of collective action. Here, on the basis of our observations, it now appears likely that the action of designating private goods as commons can help achieve a collective interest, and that the collective characteristic of these goods is not a problem, but rather a solution. It opens up the way to collective design processes of new modes of governance to manage sustainably agricultural landscapes. Thanks to the knowledge production in ecology, grasslands have been identified as a potential infrastructure to sustain the provision of agro-ecosystem services. However the stakeholders have then to agree on how to manage this infrastructure to provide the ecosystem services they select. The legitimacy of actors who will take over the assessment of the agro-ecosystem trajectory remains however an open question. Are an agricultural cooperative, or a research center, legitimate to determine the agro-ecosystem trajectory? This research-action program aims to generate new knowledge to identify relevant parameters values, but also tools and methods for the design and multi-criteria assessment of actions to implement: shared evaluation grids, simulation tools, ad-hoc method of collective design.

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